UPPDRAG 2000
VATTENFALLS PROJEKT
RATIONELL
ENERGIANVÄNDNING

1989-10-09

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# AN END-USE PERSPECTIVE ON ELECTRICITY PRICE RESPONSIVENESS

**"An Investigation of Price versus Non-Price Factors in Sweden and Denmark, with Special Emphasis on the Household Sector".**

Vattenfall

Prepared for:
Vattenfall's Project UPPDRAG 2000
Stockholm

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**September 1989**

## APPENDIX A: REVIEW AND DISCUSSION OF TRADITIONAL ELASTICITY ANALYSIS

### Published Elasticity Estimates

Although by no means exhaustive, Table A-1 demonstrates the large range in aggregate and own-price electricity elasticities as published in the size of international literature. The Table also shows a considerable overlap in short- versus long-run estimates. For electricity, the long-run elasticity estimates vary by a factor of fifty (-0.05 to -2.5) and the short-run estimates (excluding two positive estimates, one of which is for Sweden) vary by a factor of fifteen. Perhaps most striking are the results for the study of Sweden, where short-run elasticities for electricity demand estimated for the same country, and for the same end-use sector vary from -0.52 to +0.09 depending on the year studied.[155] Variation in elasticities was observed for the United States by Chern *et al*, where the calculated short-term elasticities declined steadily from -0.801 to -0.133 and long-term elasticities declined from -1.360 to -0.498 between 1955 and 1978.[156]

An equally disturbing finding is that by applying different models to the same data series, short-run price elasticity estimates can vary by a factor of more than four, even after normalizing the energy data to a typical weather year .[157] Perhaps this effect can be attributed in part to changes in the electricity-to-oil price ratio in each year.

One notable item in the Table is the pair of elasticity estimates made by ORNL for specific appliances (refrigerators and freezers). To the best of my knowledge, this is the only published effort to do so--probably due to the lack of sufficiently detailed data. Notice the significant difference in the estimates.

In practice, residential demand elasticities are constrained by price as well as the energy-use characteristics of equipment in the home (and any sector, for that matter). Kahn *et al.* describe a method of using appliance stock characteristics as parameters to define short-run "utilization" or behavioral elasticities and long-run "stock-adjustment" or saturation and efficiency elasticities, the sum of which is analogous to the conventional long-run elasticity.[158] Their results (see Table A-1) for two southern U.S. utilities: short-run elasticity -0.06 to -0.16; long-run elasticity -0.47 to -0.57.

155. L. Hjalmarsson and A. Veiderpass, *op. cit. supra*, page 17.

156. W.S. Chern and H.E. Bouis, 1988, *op. cit. supra*.

157. G. Kouris. Elasticities--science or fiction? *Energy Economics*, pp. 66-70. April 1981. Page 68.

158. E. Kahn, J. Sathaye, and D. Robbins. 1986. An engineering-economic approach to estimating the price elasticity of residential electricity demand. *Energy Economics*, April, pp. 118-126.

Table A-1. Published energy demand elasticities. (Estimates apply to the residential sector unless otherwise noted.)

| SOURCE | PRICE | INCOME |
|---|---|---|
| ELECTRICITY | (SR) = Short-run | (LR) = Long-run |
| SCANDINAVIA | | |
| Dargay and Lundin | -0.09 (SR) | 0.46 (SR) |
| Sweden | -0.62 (LR) | 0.68 (LR) |
| 1962-1976 | | |
| DFE | -0.14 (SR) | |
| Sweden | | |
| 1950-1976 | | |
| Hjalmarsson and Veiderpass | | |
| Sweden | | |
| 1960 | -0.52 (SR) | 0.68 (SR) |
| 1976 | +0.09 (SR) | 1.18 (SR) |
| 1981 | -0.27 (SR) | 1.96 (SR) |
| SEAS | -0.55 (LR) -0.15 (SR) | |
| Jorn Mikkelsson | -0.05 to -0.10 (SR) | |
| ELSAM, 1988 | -0.50 to -1.00 (LR) | |
| (all sectors) | | |
| Hjalmarsson | -0.19 to -0.24 (SR) | |
| Norway | -0.24 to -1.46 (LR) | 1.10 (SR) |
| 1957-1975 | | |
| Bohi and Zimmerman | +0.04 to -0.88 (SR) | -0.214 to 2.00 (SR) |
| 1984 | -0.05 to -2.5 (LR) | 0.12 to 3.00 (LR) |
| Kahn et al., | -0.06 to -0.16 (SR) | |
| United States | -0.47 to -0.57 (LR) | |
| 1970-1992 | | |
| EPRI | -0.101 (SR) | 0.077 (SR) |
| United States | -1.052 (LR) | 0.802 (LR) |
| Chern et al. | -1.075 | 0.771 |
| 8 OECD Countries | | |
| 1960-1979 | | |
| Lundin | -0.07 to -0.61 (SR) | 0.03 to 0.30 (SR) |
| United States | -0.78 to -2.50 (LR) | -0.46 to 1.94 (LR) |
| (Range of 11 studies) | | |
| 1929-1972 | | |
| Parti and Parti | -0.58 (SR) | 0.15 (SR) |
| United States | | |
| 1980 | | |
| Oak Ridge National Lab | | |
| U.S. Refrigerators, 1978 | -0.20 | |
| U.S. Freezers, 1976 | -0.34 | |

AGGREGATE (Total Energy)

Table A-1 (continued).

| | | |
|---|---|---|
| IEA (res and com and agriculture) | | |
| North America | -0.60 (LR) | |
| Pacific OECD | -0.70 (LR) | |
| Europe OECD | -0.55 (LR) | |
| All OECD | -0.59 (LR) | |
| 1973-1982 | | |
| Pindyck | -1.05 to -1.15 (LR) | 1.00 |
| 9 OECD Countries | | |
| 1960-1974 | | |
| Griffin (res and com) | -0.8 (LR) | 1.39 (LR) |
| 18 OECD Countries | | |
| 1960-1972 | | |
| Nordhaus (res and com) | -0.7 (LR) | 1.09 (LR) |
| 7 OECD Countries | | |
| Matsui (res and com) | | |
| Japan 1965-1972 | -0.220 | 1.70 |
| Japan 1965-1977 | -0.022 | 1.11 |
| Baughman & Joskow | -0.16 (SR) | 0.20 (SR) |
| United States | -0.63 (LR) | 0.80 (LR) |
| 1968-1972 (res and com) | | |
| Chern | -0.71 (LR) | 0.44 (LR) |
| United States | | |
| 1972 | | |
| Chern et al. | -0.513 | 0.771 |
| 8 OECD Countries | | |
| 1960-1979 | | |
| Parikh and Rothkopf | | |
| United States | | |
| Residential | -0.271 (LR) | |
| All Sectors | -0.188 (LR) | |
| 1970 | | |
| Kouris | -0.120 to -0.539 (SR) | 0.523 to 1.000 (SR |
| United Kingdom | | |

1961-1979, range corresponds the the results from applying six estimat estimation methods to the same price and consumption data.

(References overleaf)

Table A-1 references not previously cited in the main text.

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Mikkelsson, J. ELSAM Private communication. May 20, 1988.

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SEAS estimate is for 1983 and shown here are the averages of the rates -0.5 to -0.6 (long-run) and -0.13 to -0.18 (short run), as reported by the Danish Ministry of Energy (1986) in (Redegoerelse om Elafgifter og -tariffer) page 68.

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**Usefulness of Elasticity-based Analyses in Electricity Planning**

The preceding discussion suggests that the elasticity approach has serious limitations, both technical and conceptual. It is especially disturbing that the method of definition can in itself lead to a factor or four variation in the resulting elasticity estimate. A confounding factor is that published elasticity estimates are rarely accompanied by results of significance tests. Once case that reported errors--that of Dargay and Lundin from Table A-1--showed uncertainties similar in size to the estimates themselves, although this is not to say that all estimates are poorly defined.

Still other concerns center on the application of elasticity estimates. Since aggregate (all fuels) estimates reflect a given stock of appliances, care must be taken with extrapolations into the future because the fuel mix and appliance penetrations underlying the estimates may change *for non-price reasons*. More useful results may be obtained by looking separately at each end use--but, of course, data problems make it impossible to conduct an ideal analysis.

From a more conceptual perspective, price, income, and fuel-share elasticities shed no light on the economic attractiveness of reducing demand by a given amount. As a result, elasticity-based forecasts can not reveal the range of "desirable" energy futures.

> "In keeping with the predictive orientation of long-term socio-economic and resource policy modelling and forecasting, the dominant approach to formal modelling in this area has been econometric. Econometric models, which are based upon the statistical analysis of historical relationships among economic data, are necessarily predictive because they endogenize behavioral theory in the form of aggregate economic relationships. While econometric models can be used for scenario analysis and sensitivity testing, they are not useful for exploring futures on the basis of their physical feasibility and impacts rather than their likelihood."[159]

Of course this perspective marks a rather abrupt departure from traditional forecasting (for which the elasticity is intended). Yet, even within the predictive realm, there remain sizable problems with the elasticity method. For example, the elasticity estimate taken alone does not help policy makers to estimate the investment behavior of the energy consumer (nor for that matter of appliance manufacturers). For example, one measured elasticity of -0.5 may correspond to a sector or end-use category where energy users have a tendency to make efficiency investments with 10-year paybacks while another -0.5 elasticity measurement (e.g., for a different end use or fuel or country) may reflect efficiency investments

159. J.B. Robinson. 1988. Unlearning and backcasting: rethinking some of the questions we ask about the future. *Technological Forecasting and Social Change.*

corresponding to a 1-year payback. The importance of this potential asymmetry is that future price increases may or may not bring the cost-effectiveness of fuel switching or efficiency improvements into the range of "acceptable investments" from the perspective of the energy consumer.

Other considerations include:

- Even an accurate elasticity estimate provides little or no guidance about how to increase the existing level of price responsiveness and about which end uses (and technologies) are most likely to be affected.

- An elasticity estimate resulting from a model fit over many years represents an average value for the range of conditions that occurred over that time period. Such an estimate can mis-state price responses if the price elasticity is itself a function of price level. This phenomenon has emerged in U.S. oil demand statistics following the recent price collapse; short-run price elasticities shifted from -0.08 during 1985 to -1.8 during the first half of 1986.[160] Conceivably, this reflects an asymmetry in price-responsiveness wherein demand grows more during periods of decreasing prices than it shrinks during periods of increasing prices. Hjalmarsson and Veiderpass also claim this to be the case.[161] This hypothesis has some intuitive appeal, considering that demand growth due to structural decisions made during times of plenty can only be partly reversed (at least in the short run) by curtailing utilization. However, others find that demand is less elastic during times of falling prices.[162]

- Models fit with aggregate prices (such as those published by the International Energy Agency) can conceal price non-responsiveness of customers with discounted electricity (e.g., for heating) or overstate that for customers with high fixed charges imbedded in the price. The first factor can lead to poor forecasts if the fraction of energy purchased at a discount is changing.

- While it is interesting to compare elasticities across countries, distortions can arise when expenditures and incomes are converted to a common currency

160. M. Rodekohr. 1987. Falling world oil prices: an assessment of the impact on petroleum demand. Energy Information Administration. U.S. Department of Energy.

161. L. Hjalmarsson and A. Veiderpass, *op. cit. supra*. page 19.

162. (IEA, 1987, *op. cit. supra*, page 46); Chern and Bouis, 1988, *op. cit. supra*. page 217. A key reason for this effect is that structural development during early years (e.g. increasing appliance saturations) results in a large observed elasticity—although the elasticity estimate in and of itself does not shed any light on the details of *why* demand was price-responsive—whereas in later years, the structure is "set" in place and demand may be more strongly driven by efficiency improvement. Chern and Bouris state that the smooth decline in observed elasticities suggests that a rapid increase in electricity prices is not an important factor and that, rather, the driving force is structure.

(although Chern et al., (1983) has shown that adjusting for purchasing power parities modifies the results only slightly for industrialized countries).[163]

- Other considerations when comparing the own-price elasticities of various countries include: variations in cross-price ratios; fuel substitution opportunities, e.g., natural gas may be not be available in all cases being compared; differences in the cost-effectiveness of switching to alternate fuels or of increasing efficiency; or differing mixes of end uses and thus incommensurate opportunities for fuel switching and/or utilization (e.g., space heating offers a high degree of flexibility whereas cooking offers little).

- In addition to price and income elasticities, there are also elasticities to the purchase price of energy-using equipment. So, insofar as increased efficiencies correspond to higher sales prices, the effect of the price will be to some extent counteracted by the reluctance of the consumer to spend more on the better appliance. Estimates for Freezers (-0.79) and for refrigerators (-0.33) are in both cases larger than the corresponding price elasticities (see Table A-1).[164]

- A specific set of problems arise when an elasticity estimate based on the past is used to project future demand responsiveness:

  - Elasticities could be expected to vary over time in response to various stages of efficiency improvement in a given sector. In particular, price-responsiveness may be expected to decline as the most cost-effective technical opportunities are taken advantage of. That is, as consumers "skim the cream" by choosing quick-payback measures marginal investments will require relatively large price increases to be considered cost-effective. Traditional economics could offer the explanation that the consumer encounters a large discontinuity in the "supply curve" of conserved energy and requires a very large price increase to invest further in efficiency or fuel switching (see Figure 38 in the main report).

  - Technological advances and/or policy, informational, incentives, or pricing efforts can stimulate price responses (via new technological options) not previously possible. In the preceding cases, the elasticity does not appear to be needed or useful in the planning process.

163. Chern *et. al. op. cit. supra.*
164. U. S. DOE, 1988, *op. cit. supra*, page C-43.

- Low relative electricity prices encourage penetration of electric end uses. It is of course incorrect to assume that these end uses would as quickly, easily, and fully "un-penetrate" were the prices to change. (This is especially so with non-substitutable end uses, e.g. refrigeration.) A very important instance of this asymmetry, in the case of Sweden, is the large number of electrically-heated homes constructed under the SBN and ELAK standards. The high efficiency of these homes renders envelope retrofits to reduce space heating very costly. The capital costs of switching to fuel-fired furnaces are also extremely high.

- Historic elasticities may reflect periods of rapid penetration of new end-uses. Since penetration is a finite process that typically follows an "S-curve", electric demand growth due to increased numbers of appliances will ultimately slow roughly to the rate of housing construction, regardless of the price environment. The corresponding elasticity will also decline. At a more aggregate level, S-curve behavior is not as predictable because new end uses, structural change, etc lead to changes in the level of demand for energy services.

- If energy users do not pay for energy in proportion to their consumption (as is the case for apartment dwellers where the monthly bill is averaged over all tenants) then the elasticity may greatly under-estimate the demand response were the metering or cost-allocation systems to be altered.

- Consumer attitudes can change over time. The oil-crisis psychology of the 1970's contributed in a significant way to large price responses. This may not always be the case.

- The stimuli of "information" can change. This includes the visibility of energy concerns in the media, the format and frequency of utility bills, product labeling, etc.

- The *pattern* of price change can be as important as the magnitude, e.g. if increases are introduced quickly versus gradually or if the tariff structure is changed. For example, were the method of ratebasing new power stations to change (and thus the timing of rate increases to consumers), one might also expect a change in elasticity.

* * * *

The previous discussion suggests that the application of traditional elasticity methods may do little to increase electricity planners' confidence in the price-related aspects of their demand forecasts. Even assuming that the elasticity can be accurately computed, the following information would have to be available (and accurate):

1. Forecasts of all fuel prices, in addition to electricity
2. Estimates of the availability of future efficiency technologies
3. Estimates of the future incremental costs of efficiency improvements
4. Adjustments for the asymmetry of elasticity estimates made during periods of declining prices to the conditions of increasing prices
5. Projections of non-price effects (including many forms of structural change)

The preceding review of the elasticity literature points to a need for alternate methods of viewing the responsiveness of electricity demand to price. One way to attempt this--as has been done in this study--is by comparing the development in the structure and intensity of electricity demand in two countries with significantly different prices.

In conclusion, econometric models of energy demand can generate strong results by using strong assumptions. The above discussion points to the conclusion that elasticities seem to behave more like *variables* than like parameters. This shakes the foundations of what an elasticity is supposed to be and what it is supposed to be useful for. Planners must take care to weigh the underlying uncertainties. Models aside, electricity demand is ultimately determined by consumer decision.